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Title of the Invention:
Single Crystalline Semiconductor Thin Film Substrate Liquid Crystal Light Valve Device

S P E C I F I C A T I O N

1. Title of the Invention
Single Crystalline Semiconductor Thin Film Substrate Liquid Crystal Light Valve Device

2. Scope of the Claim
1. A liquid crystal light valve device comprising:

a complex substrate including an electrically insulating carrier layer and a single crystalline semiconductor thin film layer;

a pixel array including a group of pixel electrodes for defining a pixel region and a group of switch elements for feeding the individual pixel electrodes selectively with an electric power, and formed integrally on said single crystalline semiconductor thin film layer;

a facing substrate arranged to face said complex substrate at a predetermined spacing;

a liquid crystal layer filling said spacing and changed in a predetermined orientation state to effect optical modulations in accordance with the quantity of the electric power fed selectively to the individual pixel electrodes; and

orientation means having regular corrugations formed selectively in the pixel region for retaining the liquid crystal layer in said predetermined orientation state.

2. A liquid crystal light valve device as set forth in Claim 1, wherein said orientation means includes regular corrugations formed on the surfaces of the individual pixel electrodes.

3. A liquid crystal light valve device as set forth in Claim 1, wherein said orientation means includes regular corrugations formed on the surface of a passivation film coating the pixel electrodes.

4. A liquid crystal light valve device as set forth in Claim 1, wherein said orientation means includes regular corrugations formed on the surface of a switch element isolating field oxide film arranged under the pixel electrodes.

5. A liquid crystal light valve device as set forth in Claim 1, wherein said orientation means includes regular corrugations formed on the surface of said carrier layer positioned under the pixel electrodes.

6. A liquid crystal light valve device as set forth in Claim 1, wherein said regular corrugations are channels arrayed in one direction and at a constant spacing for retaining the liquid crystal layer in a unidirectionally oriented state.

7. A liquid crystal light valve device as set forth in Claim 6, wherein said channels are periodically changed in

their width size in the one direction for keeping the liquid crystal layer in a unidirectional tilt orientation state.

8. A process for manufacturing a liquid crystal light valve device, comprising:

a first step of preparing a complex substrate by bonding a single crystalline semiconductor substrate to an electrically insulating carrier layer and subsequently by polishing said complex substrate semiconductor substrate to form a single crystalline thin film layer;

a second step of providing a group of pixel electrodes for defining a pixel region and a group of switch elements for feeding the individual pixel electrodes selectively with an electric power, by forming a pixel array integrally with said single crystalline semiconductor thin film layer;

a third step of providing orientation means on the surface of the complex substrate by forming regular corrugations selectively with respect to the pixel region;

a fourth step of superposing the facing substrate on the complex substrate through a predetermined spacing; and

a fifth step of providing a liquid crystal layer oriented by the orientation means, by filling said spacing with a liquid crystal substance.

9. A manufacture process as set forth in Claim 8, wherein said third step includes a step of forming regular corrugations by the photolitho-etching.

10. A manufacture process as set forth in Claim 8, wherein said third step includes a step of forming regular corrugations by irradiating an energy beam.

3. Detailed Description of the Invention

[Application Field in Industry]

The present invention relates to an active matrix type

liquid crystal light valve device employing a semiconductor thin film substrate and, more particularly, to a technique for orienting a liquid crystal.

[Prior Art]

The active matrix type light valve device has a relatively simple principle. Pixel electrodes composing individual pixels are equipped with corresponding switch elements, which are turned ON, when specific pixels are to be selected, but otherwise left in the OFF state. In the active matrix type liquid crystal light valve device employing a semiconductor thin film substrate, the switch elements are formed in the semiconductor thin film which is deposited on the surface of a glass substrate composing a liquid crystal panel. These switch elements are ordinarily made of thin film type insulated gate field effect transistors.

In the active matrix type light valve device of the prior art, the thin film transistors are formed on the surface of an amorphous silicon thin film or a polycrystalline silicon thin film which is deposited on a glass substrate. These amorphous silicon thin film and polycrystalline silicon thin film can be easily formed over the glass substrate by using the vacuum evaporation or the sputtering method or the chemical vapor deposition method so that they are suited for manufacturing an active matrix device of a relatively large screen.

[Problems to Be Solved by the Invention]

However, the active matrix type light valve device of the prior art employing the amorphous silicon thin film or the polycrystalline silicon thin film is not always suited for the miniaturization and high density of the pixels. In recent years, there has been enhanced a demand for the light

valve device having the miniaturized pixels of high density. This miniature light valve device is employed as the primary image forming face of a projection type image apparatus, for example, so that it can be applied to a projection type Hi-Vision TV set. If the LSI manufacture technique or the fine semiconductor manufacture technique can be employed, it is thought possible to realize a micro light valve device which has a pixel size of the order of 1 micrometer and a total size of several centimeters.

When the amorphous or polycrystalline silicon thin film of the prior art is employed, however, it is extremely difficult to form the switch elements of sub-micron or micron order by applying the LSI manufacture technique directly. In the case of the amorphous silicon thin film, for example, the film forming temperature is at about 380°C so that a hot treatment necessary for the miniaturization technique or LSI manufacture technique cannot be executed. In the case of the polycrystalline silicon thin film, on the other hand, the crystal particles have a size of several microns so that the miniaturization of the switch elements is necessarily restricted. In addition, the film forming temperature of the polycrystalline silicon thin film is at about 600 °C to make it difficult to fully exploit the LSI manufacture technique requiring a high temperature treatment of 1,000 °C or higher. As has been described hereinbefore, the active matrix type light valve device employing the amorphous or polycrystalline silicon thin film of the prior art has a problem that it is practically difficult to realize the integration density and the chip size like those of the ordinary semiconductor integrated circuit elements.

In view of the aforementioned problems of the prior art, the invention has a general object to provide an active

matrix type light valve device which includes groups of miniaturized switch elements and pixel electrodes of high density.

Here, a liquid crystal is generally employed as the electrooptical modulating substance to be used in the light valve device in the prior art. The liquid crystal is filled in a pair of substrates arranged to face each other through a predetermined spacing, and its molecules are arrayed in a predetermined direction. In order to realize this arrayed state of the liquid crystal molecules, the inner surfaces of the substrates are subjected to the so-called "orientation treatment." This orientation treatment is generally performed by rubbing the substrate surfaces in one direction with cotton cloth or the like. When the elements are integrated in a high density in accordance with the aforementioned general purpose of the invention, however, the corrugations on the surface of the semiconductor thin film substrate become prominent with respect to the pixel size, thus raising a problem that the orientation treatment of the prior art by the rubbing cannot be executed. Specifically, the homogeneous rubbing treatment is made difficult by the corrugations of the substrate surface to raise a problem that the quality of the display image degrades. Another problem is that the switch elements, as miniaturized to the sub-micron order are broken by the rubbing treatment. Moreover, there is produced dirt or dust larger than the pixel size by the rubbing treatment, thus raising a problem that the optical transmissivity of the pixels is lowered.

In view of the aforementioned problems of the rubbing treatment of the prior art, the invention has a featuring object to provide an active matrix type liquid crystal light

valve device which has such a liquid crystal orientation structure as will exert no adverse affect on the miniaturized switch elements and pixel electrodes.

[Means for Solving the Problems]

In view of the prior art thus far described and so as to achieve the general and featuring objects of the invention, the single crystalline semiconductor thin film substrate liquid crystal light valve device employs a complex substrate including an electrically insulating carrier layer and a single crystalline semiconductor thin film layer. The pixel array is integrated in high density by applying the LSI manufacture technique directly to the single crystalline semiconductor thin film layer. The pixel array is composed of a group of pixel electrodes for defining a pixel region and a group of switch elements for feeding the individual pixel electrodes selectively with an electric power. A facing substrate is arranged at a predetermined spacing to face the complex substrate having the pixel array formed. The spacing between the two substrates is filled with a liquid crystal layer. This liquid crystal layer is kept in a predetermined orientation state and is changed in the orientation state to effect optical modulations in accordance with the quantities of electricity fed selectively to the individual pixel electrodes. In the pixel region, moreover, there are selectively formed regular corrugations to constitute orientation means for retaining the liquid crystal layer in a predetermined orientation state.

These regular corrugations can be formed on the surfaces of the individual pixel electrodes. Alternatively, the regular corrugated pattern may be formed on the surface of a passivation film coating the pixel electrodes. Moreover,

the regular corrugated pattern may be formed on the surface of a switch element isolating field oxide film arranged under the pixel electrodes. Alternatively, the regular corrugated pattern may be formed on the surface of a complex substrate carrier layer positioned under the pixel electrodes.

The regularly corrugated pattern is composed of channels arrayed in one direction and at a constant spacing, for example, and has a function to hold the liquid crystal layer in a unidirectionally oriented state. Moreover, the channels may be periodically changed in the width size in one direction and may have a function to hold the unidirectional tilt orientation state of the liquid crystal layer.

The single crystalline semiconductor thin film substrate light valve device thus far described can be manufactured by the following steps. Specifically, a single crystalline semiconductor substrate such as a silicon wafer of high quality is bonded to an electrically insulating carrier layer such as a quarts substrate. After this, the silicon wafer is polished to form a single crystalline silicon thin film layer. This single crystalline silicon thin film layer retains the high quality of the silicon wafer as it is so that the LSI manufacture technique can be applied directly to the single crystalline silicon thin film layer. Next, the pixel array is integrated in a high density by employing the LSI manufacture technique for the single crystalline silicon thin film layer. This pixel array includes a group of pixel electrodes for defining a pixel region and a group of switch elements for feeding the individual pixel electrodes selectively with the electric power. The individual switch elements are made of insulated gate field

effect transistors which are formed in the single crystalline silicon thin film layer. Next, a regularly corrugated pattern is selectively formed with respect to the individual pixel regions to provide orientation means on the surface of the complex substrate. Subsequently, a facing substrate is superposed over the complex substrate through a predetermined spacing. At this time, the inner surface of the facing substrate is also subjected to an orientation treatment. Finally, the spacing, as formed between the paired substrates, is filled with a liquid crystal substance to provide a liquid crystal layer which is oriented according to orientation means.

The aforementioned regularly corrugated pattern can be formed highly accurately and homogeneously in the pixel region by the photolitho-etching, for example. Alternatively, the regularly corrugated pattern can be formed by sweeping and irradiating the pixel region with a high energy beam.

[Functions of the Invention]

According to the invention, as has been described hereinbefore, there is employed the complex substrate which as the double-layer structure includes an electrically insulating carrier layer and a single crystalline silicon thin film layer formed over the carrier layer, and the single crystalline silicon thin film layer has qualities similar to those of a silicon wafer made of a single crystalline silicon bulk, for example. By employing the LSI manufacture technique or miniaturization technique in the single crystalline semiconductor thin film layer, therefore, the switch element group and the pixel electrode group can be formed integrally in a high density. As a result, the integrated circuit chip thus obtained has a remarkably high

pixel density and a remarkably small pixel size so that it can construct a miniaturized highly accurate active matrix type liquid crystal light valve device.

In addition, the orientation means for arraying the liquid crystal molecules is constructed of the regularly corrugated pattern which is selectively formed in the pixel region. This makes it possible to establish the homogeneous liquid crystal orientation state without being adversely affected by the undulations of the complex substrate surface. On the other hand, the regularly corrugated pattern can be selectively formed with respect to the pixel region by the photolitho-etching or the sweeping irradiation with a high energy beam, so that the switch elements arranged in the vicinity of the pixel region are not damaged. In addition, the method of forming those regularly corrugated pattern employs the semiconductor manufacture process so that the substrate surface can be kept clean.

[Embodiments]

The preferred embodiments of the invention will be described in detail with reference to the accompanying drawings. Fig. 1 is a schematic exploded perspective view showing one embodiment of a liquid crystal light valve device according to the invention. As shown, the light valve device is constructed to include a complex substrate 1, a facing substrate 2 arranged to face the complex substrate 1 at a predetermined clearance, and a liquid crystal layer 3 filling the clearance. In the complex substrate 1, there are formed pixel electrodes 4 for defining pixels and corresponding switch elements 5 for feeding electric powers to the pixel electrodes 4 selectively.

The complex substrate 1 has the double-layer structure

which is composed of a carrier layer 6 of quartz and a single crystalline silicon thin film layer 7. In addition, a polarizing sheet 8 is adhered to the back side of the quartz carrier layer 6. Moreover, the aforementioned switch elements 5 are integrated in a high density in the single crystalline silicon thin film layer 7 by using the LSI manufacture technique. The switch elements 5 are made of insulated gate field effect transistors. The source electrodes of the transistors are connected with the corresponding pixel electrodes 4; the gate electrodes of the same are connected with scanning lines 9; and the drain electrodes of the same are connected with signal lines 10. In the periphery of a pixel array composed of a group of pixel electrodes 4 and a group of switch elements 5, there is formed an X-driver 11 which is connected with the signal lines 10 in columns. There is further formed a Y-driver 12 which is connected with the scanning lines 9 in rows. With this construction, the individual switch elements 5 are selected in the linear order through the scanning lines 9 by the Y-driver 12 so that the selected switch elements 5 are selectively powered through the signal lines 10 by the Y-driver 12.

In the pixel region defined by the individual pixel electrodes 4, as shown, there is formed orientation means 13 which is formed of a periodically corrugated pattern. This orientation means 13 is selectively formed with respect to the pixel region so that it exerts no adverse affect on the switch elements 5 existing in the vicinity of it.

The facing substrate 2 is constructed to include a glass carrier 14, a polarizing sheet 15 adhered to the outer side of the glass carrier 14, and a common electrode 16 formed on the inner side of the glass carrier 14. The common

electrode 16 is coated all over its surface with an orientation film 17.

The liquid crystal layer 3 is clamped between the complex substrate 1 and the facing substrate 2 making a pair. Moreover, the upper and lower surfaces of the liquid crystal layer 3 are in face-to-face contact with the orientation means 13 and the orientation film 17. These orientation means 13 and orientation film 17 act to bring the liquid crystal layer 3 into a predetermined orientation state. In response to a voltage to be applied between the pixel electrodes 4 and the common electrode 16, the liquid crystal layer 3 performs optical modulations. This orientation state of the liquid crystal layer 3 may be established at least in the pixel region. Thus, the orientation means 13 is selectively formed with respect to the pixel region which is defined at least by the pixel electrodes 4.

Fig. 2 is a partially enlarged schematic diagram taking up one pixel region of the liquid crystal light valve device shown in Fig. 1. In this embodiment, the liquid crystal layer is made of a nematic liquid crystal material. The nematic liquid crystal molecules 18 are characterized to be easily oriented in their longer axis directions. At the pixel region of the complex substrate 1, there is formed the orientation means 13. This orientation means 13 is composed of the channels which are arrayed in the longitudinal direction and at a constant spacing, to establish the longitudinally unidirectional oriented state of the liquid crystal molecules 18. In other words, the liquid crystal molecules 18, as existing in the vicinity of the surface of the complex substrate 1, are arrayed along the channels. According to the invention, as has been described

hereinbefore, the pixels can be miniaturized in size by using the LSI manufacture technique such that the size of the pixel region is set to a square of 10 microns. In this case, the spacing or pitch of arranging the arrayed channels is preferably set to about 1 micron. This fine pitch pattern can be formed by the photolithography or etching. Specifically, the pixel region is coated with a photoresist and is then exposed and developed with a predetermined mask pattern. The photoresist having failed to set is removed, and the pixel region surface is then anisotropically etched so that the channels can be formed. For the highly accurate patterning, the exposure source is preferably exemplified by an ultraviolet ray or X-ray.

The orientation film 17 is also formed on the inner surface of the facing substrate 2. In this embodiment, this orientation film 17 is also formed of the channels arrayed at a constant pitch. However, these channels are arrayed in the transverse direction. As a result, the liquid crystal molecules 18, as existing in the vicinity of the surface of the facing substrate 2, are oriented in the transverse direction. Since the orientation directions are different by 90 degrees between the upper and lower substrates, as shown, the liquid crystal molecules 18 are accordingly turned by 90 degrees. That is, there is established the so-called "twist orientation of the nematic liquid crystal." As a result, the axis of polarization of the light to pass through the twist nematic liquid crystal layer is turned by 90 degrees.

When an electric field is applied between the pixel electrodes and the common electrode, on the other hand, the liquid crystal molecules 18 are arrayed in the direction of electric field, that is, at a right angle with respect to

the substrates so that they lose the optical rotatory power with respect to the incident light. This transition can be optically detected by the paired polarizing sheets which are arranged over and under the liquid crystal layer. In short, the incident light to pass through the pixel region is transmitted or blocked depending upon the presence or absence of voltage application. Thus, the twist nematic liquid crystal layer performs electrooptical modulations for each pixel region.

Fig. 3 is a schematic diagram showing an improved modification of the orientation means in an enlarged scale by taking up one pixel of the complex substrate 1. In this modification, the orientation means 13 is composed of the channels which are formed in the pixel region surface. These channels are arrayed in one direction and arrayed at a constant spacing. As a result, the liquid crystal molecules 18 are unidirectionally arrayed according to the extending direction of those channels. The channel spacing is exemplified by 1 micron. As apparent from Fig. 3, the individual channels are periodically changed in their widths in the extending direction thereof, i.e., in the array direction of the liquid crystal molecules 18. This period is exemplified by about 3 microns. By thus changing the channel width periodically, the liquid crystal molecules 18 are oriented at a predetermined angle of inclination, i.e., at a tilt angle θ with respect to the surface of the substrate 1. In short, it is possible to realize the unidirectional tilt orientation state of the liquid crystal molecules. The pattern shape of the orientation means 13, as shown in Fig. 3, can be formed by using the fine photolithography or etching. Alternatively, the pattern

shape can also be formed by irradiating an energy beam along the channels while changing the intensity of the energy beam periodically. As a matter of fact, the orientation means 13 is formed for the film which exists on the surface of the pixel region. This film is formed by applying a polyimide film, for example. Alternatively, the orientation means 13 may also be formed on the passivation film which is made of a silicon nitride film or a silicon oxide film. Alternatively, the orientation means 13 may also be formed on the surface of the ITO film which makes the pixel electrodes defining the pixel region.

The aforementioned tilt orientation of the liquid crystal molecules is made to raise the liquid crystal molecules slightly in advance so as to fix the direction for the liquid crystal molecules to rise in response to the electric field. The ordinary twist nematic liquid crystal may have the tilt angle θ set to about several degrees. As the twist angle is enlarged as in the so-called "super twist nematic liquid crystal", however, the tilt angle also has to be set to 5 degrees or more. A desired value of the tilt angle θ of the liquid crystal molecules can be achieved by suitably setting the pitch spacing and a change period of width of the channels composing the orientation means 13. Thus, the modification shown in Fig. 3 is effective especially for the light valve device using the super twist nematic liquid crystal.

With reference to Figs. 4 to 7, here will be described examples of the specific construction of the orientation means according to the invention. Fig. 4 is a schematic section showing an example, in which regular corrugations are formed on the surface of the pixel electrodes, by taking

up one pixel region of the complex substrate. As shown, a quartz substrate 41 is coated on its surface with a single crystalline silicon thin film layer 42. This single crystalline silicon thin film layer 42 is selectively thermally oxidized so that it is partially changed into a field oxide film 43. The remaining portion of the single crystalline silicon thin film layer 42 defines the element region to form a switch element 44. The switch element 44 has a gate electrode 46 which is arranged through a gate insulating film 45 over the single crystalline silicon thin film layer 42 left in an island shape. The single crystalline silicon thin film layer 42 forms a source region 47 at its righthand side portion by an impurity diffusion. A drain region 48 is formed, too, at the lefthand side portion by the impurity diffusion. These gate electrode 46, source region 47 and drain region 48 constitute the switch element 44 which is made of an insulated gate field effect type transistor. On the surface of the field insulating film 43, there are formed of a transparent pixel electrode 49 which is made of the ITO or the like. The pixel electrode 49 is electrically connected at its one end with the source region 47 of the transistor. There is further formed a drain electrode 50 which is connected with the drain region 48.

In the modification shown in Fig. 4, orientation means 51 is composed of regular corrugations which are formed on the surface of the pixel electrode 49. These regular corrugations are channels which are arrayed in one direction and arrayed at a constant spacing. The channels have a spacing set to 1 to 2 microns and a depth of 200 to 2,000 angstroms. This channel pattern can be easily formed by employing the photolithography and anisotropic etching.

Next, a modification is shown in Fig. 5. The portions identical to the components of Fig. 4 are designated by the identical reference numerals, and their description will be omitted. What is different from the embodiment of Fig. 4 is that the orientation means 51 is formed not on the surface of the pixel electrode 49 but on the surface of a passivation film 52. This passivation film 52 is made of a silicon nitride film or a silicon oxide film for protecting the switch element 44 intrinsically. In this modification, the passivation film 52 is extended as far as the pixel region which is defined by the pixel electrode 49. This passivation film 52 is subjected to the photolithography and anisotropic etching to form the orientation means 51 which is composed of a plurality of channels.

Another modification is shown in Fig. 6. The portions identical to the components of Fig. 4 are designated by the identical reference numerals, and their description will be omitted. What is different from the embodiment of Fig. 4 is that the orientation means 51 is composed of the regular corrugations which are formed on the surface of the field oxide film 43. Before the pixel electrodes 49, more specifically, there are formed in advance in the surface of the field oxide film 43 the channels which are arrayed at a predetermined spacing. By superposing the pixel electrodes 49 on the field oxide film 43 having the channels, the corresponding channels are further formed in the surface of the pixel electrodes 49.

Still another modification is shown in Fig. 7. The portions identical to the components of Fig. 4 are designated by the identical reference numerals, and their description will be omitted. What is different from the embodiment of Fig. 4 is that the orientation means 51 is

formed in advance on the surface of the quartz substrate 41. When the field oxide film 43 is superposed on the surface of the quarts carrier layer 41 having the channels, as shown, the corrugations are formed to correspond to the field oxide film 43. When the pixel electrode 49 is superposed along the corrugations, moreover, the corresponding corrugations appear on the surface. As a matter of fact, the liquid crystal molecules are arrayed by the corrugations. If the channels are thus formed in advance in the surface of the quartz substrate 41, the orientation means 51 can be automatically formed without any special working for forming the orientation means at an intermediate step.

With reference to Figs. 8(A) to 8(G), here will be finally described a process for manufacturing a liquid crystal light valve device according to the invention. At a step shown in Fig. 8(A), there are prepared a quartz substrate 61 and a single crystalline silicon substrate 62. This single crystalline silicon substrate 62 is preferably made of a high-quality silicon wafer to be used in the LSI manufacture, and has a crystal orientation of a uniformity within a range of <100> 0.0 ± 1.0 and a single crystal lattice defect density of 500 defects/cm^2 or less. The surface of the quartz substrate 61 thus prepared and the surface of the silicon wafer 62 are finished smooth at first. Subsequently, the quartz substrate and the silicon wafer are thermally bonded to each other by superposing and heating the two surfaces thus finished smooth. By this thermally bonding treatment, the quartz substrate 61 and the silicon wafer 62 are firmly bonded to each other.

Subsequently at a step shown in Fig. 8(B), the surface of the silicon wafer is polished. As a result, there is formed on the surface of the quartz substrate 61 a single

crystalline silicon thin film 63 which is polished to a desired thickness (e.g., several microns). Here, the polishing treatment may be replaced by an etching treatment for thinning the silicon wafer. The single crystalline silicon thin film 63 thus obtained retains the quality of the silicon wafer substantially as it is, so that it can provide a semiconductor substrate material which is remarkably excellent in the homogeneity of the crystal orientation and the crystal defect density.

In the prior art, there have been known a variety of substrates for the semiconductor device which has a laminated structure having an electrically insulating carrier layer and a single crystalline silicon thin film layer. This is the so-called "SOI substrate." This SOI substrate is achieved, for example, by depositing a polycrystalline silicon thin film on the surface of a carrier substrate made of an insulating substance by using the chemical vapor deposition method, and subsequently by recrystallizing the polycrystalline thin film into a single crystalline structure by subjecting it to a heat treatment by a laser beam irradiation. However, the single crystal, as obtained by recrystallization of a polycrystal, does not always have a homogeneous crystal orientation but has a large crystal defect density. For these reasons, it is difficult to apply the LSI manufacture technique to the SOI substrate, which is manufactured by the existing method, like the single crystalline silicon wafer of high quality.

At a next step shown in Fig. 8(C), the single crystalline silicon thin film 63 is selectively subjected to a thermal oxidation. This thermal oxidation is executed through a mask for shielding only the element region to form the switch element transistor, so that a field oxide film 64

is formed to enclose the element region. This field oxide film 64 is achieved by thermally oxidizing the single crystalline silicon thin film 63 completely of its thickness, to form an optically transparent and ideal element separating region.

At a subsequent step shown in Fig. 8(D), the surface of the single crystalline silicon thin film 63, as left only in the element region, is subjected again to the thermal oxidation. As a result, there is formed on the surface of the single crystalline silicon thin film a gate insulating film 65 which has an extremely thin thickness. On the substrate surface, moreover, there is deposited a polycrystalline silicon thin film by using the chemical vapor deposition, for example. This polycrystalline thin film is etched through a mask, as worked to a desired pattern, to form a gate electrode 66.

At a step shown in Fig. 8(E), moreover, an impurity is introduced. By employing the ion implantation, for example, the single crystalline silicon thin film 63 is doped with an ionized impurity through the gate insulating film 65 by using the gate electrode as a mask. As a result, a source region 67 and a drain region 68 are formed, as shown.

At a step shown in Fig. 8(F), there is laminated a pixel electrode 69 on the surface of the field oxide film 64. This one end is electrically connected with the source region 67 through a contact hole 70a which is formed in a portion of the gate insulating film 65. A signal line 71 is also formed and electrically connected with the drain region 68 through a contact hole 70b. Subsequently, the substrate is coated on its surface with a transparent passivation film 72 which is made of the PSG. As a result, the switch element transistor is completed. However, the surface of

the pixel electrode 69 is not coated with the transparent passivation film 72 but is exposed to the outside. In this exposed surface, there are formed linear channels having regular corrugations, i.e., a constant pitch to provide orientation means 73.

The process of these linear channels will be described with reference to Fig. 9. This embodiment makes use of the surface treatment using the sweep irradiation of an energy beam. This energy beam is exemplified by a laser beam, an ion beam or an electron beam. This energy beam is raster-scanned to irradiate the surface of the pixel electrode 69. As a result, the pixel electrode surface is worked to form the linear channels along the sweeping locus of the energy beam. When the laser beam is employed, for example, the irradiated portions are heated and melted to form the channels by the thermal deformations. Alternatively, the laser beam of a higher energy may be irradiated to evaporate the atoms existing on the surface of the pixel electrode so that the chemical reaction with the ambient gas may be promoted to form the channels. When the ion beam is employed, on the other hand, the surface of the pixel electrode 69 is selectively sputter-etched along the irradiation locus to form the channels. Alternatively, thermal deformations may be caused to form the channels as with the laser beam. In another example, the surface of the pixel electrode 69 may be coated with a polyimide film and then swept and irradiated with the electron beam to form the channels. The polyimide is an especially excellent material for the liquid crystal orientation. If the channels are thus formed by the irradiation of the energy beam, the pixel region can be selectively subjected to the surface treatment so that the near switch elements are not damaged. Since the

energy beam irradiation is performed on the substrate which is confined in a vacuum chamber, on the other hand, neither dust nor fluff sticks so that the substrate surface can be kept clean. It is quite natural that the linear channels may be formed by combining the photolithography and the anisotropic etching, as described hereinbefore, in place of the energy beam irradiation.

Reverting to Fig. 8(C), here will be finally described a step of assembling the liquid crystal panel. Independently of the completed complex substrate, there is prepared a facing substrate 74. This facing substrate 74 is constructed to include a glass carrier 75, a common electrode 76 formed on the surface of the carrier 75, and an orientation film 77 coating the surface of the common electrode 76. This orientation film 77 is formed by applying a polyimide film of about 50 nm and subsequently by rubbing it. Alternatively, linear grooves having a regular pitch may be formed directly in the surface of the common electrode 76 by employing the fine surface working treatment as in the orientation means 73. The use of the regularly linear channels can establish the homogeneous orientation state thereby to prevent the defects effectively. Next, the complex substrate 61 and the facing substrate 74 are adhered and fixed to each other at a predetermined spacing. In order to adhere the substrates at their peripheries, one substrate is printed on its periphery with a sealing material (although not shown) of an epoxy resin. However, an opening is prepared for confining a liquid crystal therein later. In this sealing material, there is mixed spacer particles for controlling the gap between the paired substrates. In order to make this gap uniform, moreover, the spacer particles are scattered over the substrate

surface. These spacer particles are preferably scattered avoiding the pixel region. Moreover, the paired substrates are thermocompression-molded with the sealing material, and their gap is then filled with a liquid crystal. This filling of the liquid crystal is performed by dipping the filling holes of the liquid crystal panel in the liquid crystal within a vacuum chamber. Then, the vacuum chamber is released to the atmospheric pressure, and the liquid crystal is caused to enter the panel by the external pressure. After this, the panel is heated over the clearing point of the liquid crystal and then cooled down. Then, the liquid crystal molecules are caused to exhibit a predetermined orientation state by the orientation means 73 and the orientation film 77. Finally, a pair of polarizing sheets 79 and 80 are adhered to the outer surface of the liquid crystal panel to complete the light valve device.

[Effects of the Invention]

According to the invention, as has been described hereinbefore, the liquid crystal light valve device is constructed by employing the integrated circuit chip substrate which is obtained by forming the pixel electrode group and the switch element group integrally by applying the LSI manufacture technique directly to the single crystalline semiconductor thin film layer of a high quality formed over the carrier layer. As a result, there arises an effect that it is possible to provide a light valve device having a remarkably high pixel density.

According to the invention, moreover, the orientation of the liquid crystal layer is controlled by employing the regularly corrugated face which is selectively formed with respect to the pixel region defined by the miniaturized pixel electrodes. This eliminates the problem that the

switch elements arranged in the vicinity of the pixel region are damaged, as might otherwise be encountered in the rubbing treatment of the prior art. Another effect is that the orientation control can be made without being influenced by the undulations of the semiconductor substrate having the formed elements. Since the regularly corrugated face is formed by the photolitho-etching or energy beam irradiation, the invention has an effect that neither dust nor fluff sticks to cause no orientation defect substantially, unlike the rubbing method of the prior art. Since the orientation film is formed by the surface treatment of excellent accuracy, another effect is that it is possible to control the liquid crystal orientation excellent in homogeneity and reproducibility.

4. Brief Description of the Drawings

Fig. 1 is a schematic exploded perspective view showing one embodiment of a liquid crystal light valve device according to the invention; Fig. 2 is a partially enlarged schematic diagram taking up one pixel portion of the liquid crystal light valve device; Fig. 3 is a schematic diagram showing an example of the surface structure of orientation means; Fig. 4 is a schematic partial section showing a specific example of the orientation means; Fig. 5 is a schematic section showing a modification of the orientation means; Fig. 6 is a schematic section showing another modification of the orientation means; Fig. 7 is a schematic section showing still another modification of the orientation means; Figs. 8(A) to 8(G) are step diagrams showing a process for manufacturing a single crystalline semiconductor thin film substrate liquid crystal light valve

device; and Fig. 9 is a schematic diagram for explaining a process for forming linear channels constructing the orientation means.

1 ... complex substrate	2 ... facing substrate
3 ... liquid crystal layer	4 ... pixel electrode
5 ... switch element	6 ... carrier layer
7 ... single crystalline silicon thin film layer	
8 ... polarizing sheet	9 ... scanning line
10 ... signal line	11... X-driver
12 ... Y-driver	13 ... orientation means
14 ... glass carrier	15 ... polarizing sheet
16 ... common electrode	17 ... orientation film
18 ... liquid crystal molecules.	

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